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Notes on United Kingdom Research on techniques for distinguishing between earthquakes and underground explosions

The E.N.D.C. is familiar with the history of the Experts Conference here in Geneva in 1958 and its recommendations for monitoring possible violations of a nuclear test ban treaty in all environments. Then, as now, discussions about how to distinguish between earthquakes and man-made underground explosions proved most difficult of all. This continuing difficulty is reflected in the fact that while it is still not possible to obtain agreement on this problem, a treaty banning nuclear tests in all other environments has been concluded.

When it became clear that for various reasons the control system recommended at Geneva in 1958 was unlikely to be implemented, scientists in the United Kingdom took a new look at the possibilities of detecting underground events at much greater distances than the 1000 kilometre range required for the Geneva recommendations of 1958. The thought was that seismic waves generated at such distances as would enable them to travel through the earth's homogeneous deep mantle should be much freer from the complexities introduced at shorter ranges by heterogeneities along shallower propagation paths through the earth's crust. With this concept in mind, U.K. scientists embarked on a seismic research programme to examine the possibilities of developing a detection system very different from that already recommended at Geneva.

The problem was seen as calling not only for research in all the usual seismic conditions but also as one where the seismic problem itself should be examined as one of exact measurement. The latter aspect immediately led to all recordings being made in such a way as would enable them to be processed electronically. By increasing the number of seismometers per station and deploying them in beam-forming arrays, by placing them in deep boreholes and by seeking lower noise sites than previously used,

the possibility of great improvements in the signal to noise ratio soon became apparent with an essentially increased ability to see the first motions of the compressional or P waves arriving from a seismic source.

It was found that arrays of this particular type offered the greatest promise of advancement. As well as offering a signal to noise improvement in proportion to the square root of the number of seismometers used, they allowed the possibility of turning the array to more than one signal component velocity, thus improving the reception of later signal components, they offered an approximate determination of the direction of the source and they provided a body of data which enabled a method for determining depth of focus to be applied with considerable success. With such early encouragement scientists in the U.K. intensified their work with these arrays and established an experimental facility in U.K. to develop array techniques and prove instrumentation. At the same time, in close collaboration with their colleagues in the U.S., they established a similar experimental facility in the U.S. From this work it became apparent that a completely new concept of methods could be used to detect and identify earthquakes. The main facts then emerging may be summarised as follows:

(a) Application of data processing techniques to magnetic tape recordings increased the capability of determining first motion of the first wave.

(b) Estimation of the focal depth of events could be improved.

(c) Array type stations could be operated effectively beyond 3000 kilometres, as compared with the 1000 kilometres range for the previous Geneva system.

(d) Comparative differences in the characteristics of seismic waves from earthquakes and explosions were enhanced.

These advances suggested that the seismic detection and identification required to monitor a ban on underground tests could be carried out by a relatively small number of array stations at teleseismic distances. The reduced number of station sites in turn increased the possibility of confining stations to the quietest seismic sites available and this in itself led to a significant improvement in attaining the signal to noise ratio necessary to detect the smallest events of interest.

The next stage in this research work obviously called for a specific study of explosions and earthquakes at teleseismic distances using large arrays. In the U.K.

case these have varied from about 10 to 25 kilometres in length, are of a crossed linear geometry rather than triangular or radial and are carefully sited for noise, interference, and topographical characteristics. This phase of the work is a continuing part of the research programme still being pursued by U.K. scientists.

In the development and application of these array systems there are many variants to be examined. These include array geometry, site noise level, the number and characteristics of seismometers to be deployed. The results to be reported from the very large array experiment now being carried out in the United States will be of great interest. It is hoped that the approach taken by U.K. scientists will also contribute to resolving this difficult problem of distinguishing between natural seismic events and man-made underground explosions. A corresponding statement from any other delegation which has a contribution to report would be welcome. But behind all this, many detailed technical problems arise calling for detailed technical discussion. It would therefore be greatly preferable to have the scientists working on these problems brought together to discuss their work and assess the possibilities of creating an effective monitoring system for the detection and identification of underground nuclear explosions. It may well be that an effective monitoring system will call not for one particular type of array but various types depending on local seismic and topographical characteristics, as well as costs.

In the meantime the U.K. has continually sought to exploit these new technical advances as they have come along. They made possible a new approach to an underground test ban in 1962 and the West have continued to modify their position as scientific evidence has accumulated. Some of this work has already been published and all the work carried out by U.K. scientists is now being prepared for publication. That work was the subject of a symposium sponsored by the Royal Society in January of this year and to which representatives from many countries, including the Soviet Union, were invited.

Nevertheless, with all these technical advances there still remains a residual number of seismic events at or above seismic magnitude 4.0 that would be unidentifiable by remote seismological observations alone, and which could be suspected as possible violations of a test ban, unless they could be eliminat d by some supplementary means such as on-site inspection being applied in some measure. This is the

problem that still confronts us and that prevents an extension of the test ban treaty to cover the underground environment. It remains to be seen whether further research can provide any significant improvement on the position now reached but if there is such a possibility the U.K. believe that it could only be hastened in a detailed joint examination of the advances now achieved in the Soviet Union, the United States and the United Kingdom.